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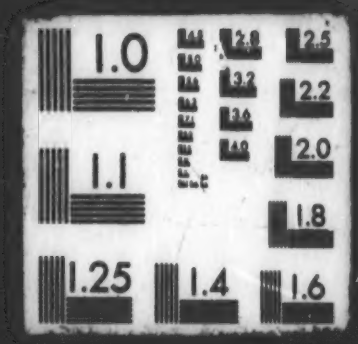

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Flue Gas Desulfurization Installations and Operations

Environmental Protection Agency, Washington, D C

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From October 18 to November 2, 1973, the Environmental Protection Agency held a national public hearing in the Washington, D.C. area to review the status of power plant compliance with sulfur oxide (SOx) air pollution emission limitations. Regulations limiting emissions of SOx have been imposed because excess quantities of SOx seriously affect human health through increased incidences of respiratory disease and damage many types of materials. The national hearing was called because power plants are the largest source of SOx emissions in the U.S., because large numbers of power plants were not yet in compliance with SOx emission limitations, and because, in most cases, only 1 1/2 years remained under the established implementation plans for these plants to achieve compliance. It was generally agreed at the hearing that FGD systems, when operating properly, would reduce SOx emissions by 85 to 90%, the levels required by most states. Questions were, however, raised by many utilities as to whether FGD systems could be made to operate reliably and as to whether an environmentally acceptable method existed to dispose of the sludge produced by some types of FGD systems. The panel additionally found that technology was available to reclaim sludge waste as landfill and that regenerable systems that do not produce any appreciable waste were available for use where throwaway systems could not be used.

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FLUE GAS DESULFURIZATION

INSTALLATIONS and OPERATIONS

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FLUE GAS DESULFURIZATION

Installations and Operations

Division of Stationary Source Enforcement
Office of Enforcement and General Counsel

INTRODUCTION

From October 18 to November 2, 1973, the Environmental Protection Agency held a national public hearing in the Washington, D.C. area to review the status of power plant compliance with sulfur oxide (SO_x) air pollution emission limitations. Regulations limiting emissions of SO_x have been imposed because excess quantities of SO_x seriously affect human health through increased incidences of respiratory disease and damage many types of materials. The national hearing was called because power plants are the largest source of SO_x emissions in the U. S., because large numbers of power plants were not yet in compliance with SO_x emission limitations, and because, in most cases, only 1 1/2 years remained under the established implementation plans for these plants to achieve compliance.

During the hearing, testimony was taken from some 50 witnesses representing electric utilities, trade associations, vendors of pollution control equipment, and other interested groups and individuals. It was generally agreed by these witnesses that flue gas desulfurization (FGD) technology must be installed on large numbers of power plants if SO_x emission requirements adopted pursuant to the Clean Air Act are to be met in the 1970's. Supplies of low-sulfur fuels are and will continue to be inadequate to provide the sole means of compliance.

It was also generally agreed at the hearing that FGD systems, when operating properly, would reduce SO_x emissions by 85 to 90%, the levels required by most states. Questions were, however, raised by many utilities as to whether FGD systems could be made to operate reliably and as to whether an environmentally acceptable method existed to dispose of the sludge produced by some types of FGD systems.

After considering the testimony, the hearing panel found that the problems allegedly affecting FGD reliability could be, and had been, solved at one plant or another, and that reliability was sufficiently demonstrated to warrant widespread commitments by utilities to FGD systems at coal- and oil-fired power plants. The panel recommended that EPA create an incentive for such commitments by vigorously enforcing reasonable schedules to comply with sulfur oxide emission limits. The panel additionally found that technology was available to reclaim sludge waste as landfill and that regenerable systems that do not produce any appreciable waste were available for use where throwaway systems could not be used.

At the time of the hearing, there were 44 FGD systems either in operation, under construction, or being planned by 23 utilities at 26 plants. Only 10 of these systems were operational, 16 under construction, and 18 planned; 8 of those under construction were projected to start-up by the end of 1974.

FGD INSTALLATION STATUS

Nearly 1 year has elapsed since the public hearing and it is appropriate to review the present status of FGD installation as an indication of the effectiveness of the hearing and EPA's follow-up program and as an indication of the continued validity of the hearing panel's conclusions.

The data covering the present status of FGD installations follows in Tables I through V. The total number of FGD units operational, under construction, or otherwise committed to has more than doubled over this year--to 93 systems at 51 plants by 39 utilities. The number of units now on-line has jumped to 19, and three additional systems are scheduled to start-up by December. In addition to the 19 operating units, 14 are now being constructed, and electric utilities have decided to install 60 more systems. Contracts have already been awarded for 17 of these 60 planned units; letters of intent have been signed for 4; bids are being taken for 7; engineering studies are underway for 17; and preliminary plans are continuing for 15.

The bulk of the 93 units will have started-up by the end of 1977. Aside from the 19 operating units and the 3 units scheduled to start-up this year, companies are projecting start-up dates of 1978 for 10 units, 1976 for 12 units, and 1977 for 19 more. The remaining 30 desulfurization systems will begin operation in 1978 or 1979, or have unknown start-up dates. Many of these 93 units are associated with new plants (47) and their installation is tied to the start-up dates of the plants.

FGD OPERATING EXPERIENCE

Recent operating experience with FGD systems has demonstrated increasingly high reliability factors with the elimination of the problems that plagued many of the early systems. Increasingly higher reliability (availability to the boiler) factors are seen both for those units recently started-up and for those units with longer operating experience. Several of these units showing high availability factors for several months can be characterized as very successful; other units, which are yet in experimental stages or still undergoing shakedown and/or adjustment, are also evidencing increasingly reliable performance. Only one type of FGD system has proven too troublesome to warrant further installations.

Many problems have, of course, been experienced with FGD system operation, particularly with earlier installations. Efforts to resolve these problems have naturally lead to improvements in system design and operation and to subsequent improvements in reliability. This clear trend to highly reliable, long-term FGD operation is best illustrated by reviewing the experience at each of the operating units.

Two of the earlier FGD installations, a lime scrubbing system and a magnesium oxide system, can be characterized as very successful by their recently demonstrated reliabilities. Louisville Gas and Electric Company's (LG&E) lime scrubbing system installed on its Paddy's Run No. 6 station started-up in April 1973 and operated until October 1973 at 70% availability to the boiler;[1] from October until shutdown in December 1973, availability was greater than 90%. Because Paddy's Run No. 6 is a peak-load boiler, the boiler, and consequently the scrubber, was shutdown in December because of a low demand for electricity. Increased demand caused LG&E to restart the boiler, controlled by the FGD system, in July 1974. Since the recent start-up, the unit has been operating at 100% availability, burning 3% sulfur coal with an SO_x removal efficiency of 90%. Early problems with this closed-loop system, which were minor and mechanical in nature, have been solved. This company is so convinced of the workability of its system, which has operated for 5 months at over 90% reliability, that it is committed to the installation of similar control systems on several additional boilers.

A recently completed 2-year FGD test project conducted by the Boston Edison Company at its oil-burning Mystic station has also been successful. Since start-up in April 1972, this 150-megawatt magnesium-oxide scrubber, which is a regenerable system producing sulfuric acid as a by-product, has experienced most of the typical process and mechanical problems. During the first year of operation, Chemico, the vendor, constantly worked on and corrected these problems. Over this period, the scrubber was available to the boiler only 17% of the time. Efficiency, however, indicated 90% sulfur oxide removal using 20% virgin magnesium oxide and 80% regenerated magnesium oxide. Beginning in June of 1973, reliability figures reached 68%, but declined slowly to 13% in December due to deterioration of the equipment from erosion and corrosion. The problems occurring pointed out the need to carefully control the chemistry of the system, and in January and February of 1974, the company and the vendor extensively overhauled the system. By March the system was 87% available to the boiler. Availability figures recently obtained were: April - 81%, May - 57%, and June - 80%. Despite the good availability figures shown, the system was shutdown as scheduled because the 2-year test period was completed. Boston Edison seems generally satisfied with the efficiency and reliability of its Mag-Ox scrubbing unit, has been quoted as calling it "a viable technology for our particular purpose,"[2] and is still considering whether it will install flue gas scrubbing systems on its other boilers.

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[1]This April to October 1973 availability factor must be viewed with caution since the boiler was down much of this time and the FGD system, while available to the boiler, was run only intermittently.

[2]Electrical Week, July 29. 1974, p.7.

Several of the more recently installed units have demonstrated very high reliability factors for several months and are not troubled with many of the problems experienced at some of the earlier installations. One of these successful units is a 32-megawatt double alkali system designed and operated by General Motors at its Parma Chevy Transmission plant in Cleveland. With an SO_x removal efficiency of 98%, the system has been available to the boiler 100% of operating time in June, July, and August 1974. Availability at start-up in April was 87%, but the scrubber was shutdown for the month of May because of unexpected pluggage by calcium carbonate deposits in the overflow line between the clarifiers and in the line from one of the clarifiers to the mix tanks; this subsequently caused overflow into the scrubber. This problem was solved during shutdown by using a polymeric flocculating agent to improve settleability and by withdrawing sludge from the clarifier more frequently. The scrubber has operated continuously since May 29 except for brief, non-scrubber related shutdowns.

Two other companies, which started-up their scrubbing units late in 1973, are also showing good performance. Arizona Public Service Co. (APS) started-up its 115-megawatt limestone scrubber designed by Research-Cottrell in December 1973. This 2-module scrubber averaged 89% availability for the 7 months from January through July 1974; module A (SO_x and particulate scrubbing) availability was 92% and module B (particulate scrubbing only) availability was 87%. Downtime was used to correct wiring, meter calibration, reheater vibration, and instrumentation problems and to repair leaks, packing glands, and reheater tube bundles. Acid condensation on the reheater tubes was solved by proper insulation, and cross baffles installed at the inlet stopped reheater vibration. System availability climbed to 93% in August after these problems were solved, and module A alone showed an availability factor of 98%. SO_x removal efficiency remained at about 92%.

Southern California Edison (SCE) started-up their 160-megawatt experimental lime scrubber in November 1973 on their Mohave unit No. 2. The system was designed by the company in conjunction with Stearns-Roger and SCE has taken over as the operating agent. This lime scrubber is half of a two-part experimental program that the company will use to decide whether it will use a lime or limestone system at its Mohave station. A 160-megawatt vertical limestone system designed by Universal Oil Products is now being constructed on Mohave No. 1 and results from this unit will be compared to experience with the Mohave No. 2 lime scrubber. The limestone system was scheduled to start-up in January 1974 in order to parallel experience at No. 2, but extensive unrelated fire damage has delayed start-up at least until October 1974.

The formal test program for Mohave No. 2 began on January 15, 1974, and the horizontal absorber has to date operated continuously at 84% availability to the boiler.

Operating experience at some of the earliest units, notably those boiler injection type units at Kansas Power and Light's Lawrence station and Kansas City Power and Light's Hawthorne station, has not been satisfactory. Both of these companies experimented with two limestone boiler injection systems using 3.5% sulfur coal. Problems with this type of system included corrosion, plugging, scaling, settling, and reheater/demister difficulties, and proved substantially more difficult than those found with tail-end type FGD systems. The companies have decided to convert their scrubbers to tail-end scrubbing with limestone and EPA knows of no plans for additional units of the boiler injection type.

Kansas City Power and Light has already converted its Hawthorne No. 4 100-megawatt scrubber to tail-end, and seems to have eliminated many of the problems it experienced with injection. A few problems remain with the recirculation system but modifications are expected to solve these problems. Combustion Engineering says that the tail-end system has operated since February 1974 with no major problems, although the demister must be cleaned by hand during boiler downtime.

Varying degrees of success are being obtained with the rest of the scrubbing units now operating. In many cases the units have not been on-line long enough to fully evaluate their performance. From the limestone systems that could be termed less successful to date than Arizona Public Service's Cholla installation, several crucial operating problems have been resolved. Kansas City Power and Light, for instance, installed an 820-megawatt system at La Cygne No. 1 that started up in June 1973. Proper design and operation of this unit is complicated by the fact that it must remove large amounts of both particulate and SO_x that result from the burning of coal having especially high sulfur and ash contents. In addition, this system was built without any means to bypass the scrubber.[3] Its initial problems are nearly all attributable to poor pH control, further emphasizing the importance of proper control of system chemistry for lime and limestone systems.

The City of Key West, operating a 37-megawatt scrubber that collects both particulates and SO_x, has found that one of its major problems is controlling dust from its unique coral grinding system.

The 2-scrubber system at Commonwealth Edison's Will County station, started-up in February 1972, showed rather poor availability factors due to many problems in the first 2 years of operation. Scrubber B was shutdown in April 1973 for internal modifications, but scrubber A has shown marked improvement recently. Availability was 72% in April of this year and 93% in May. A plugged venturi throat caused some downtime in June, but following repairs, the unit operated at 95% availability in July and 91% in August. Although Commonwealth Edison has experienced many problems at Will County, recent operation shows good signs for reliable long-term operation.

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[3]As recognized by the national hearing panel, bypass systems should be installed on scrubbing systems to make it easier to repair and adjust the system and to ensure that generating capacity is not lost during possible malfunction.

Experience at operating lime-scrubbing systems other than the successful performance at LG&E's Paddy's Run unit and Southern California Edison's Mohave unit, cannot be fully assessed at this time. Duquesne Light's Phillips 410-megawatt scrubber, on-line only for a few months, has achieved availability factors for modules 1 and 4 which were better than 70% from start-up through June. Duquesne is presently concentrating the load on these two modules and plans to place the full plant capacity on all 4 modules in the future.

Dairyland Power Coop. has been running its Alma lime-injection unit since August 1971, but only as a research system. Short test runs at 90% availability have been conducted, but no longer runs have been conducted from which reliability might be adduced.

EPA is funding a 30-megawatt research unit being operated by TVA on its Shawnee No. 10 boiler. It is designed to use lime, limestone, sodium carbonate, or air/water as the scrubbing medium and has been operating under experimental conditions since April 1972. There are 3 different types of scrubbing systems operating in parallel that are still being evaluated under a variety of operational modes.

Aside from Boston Edison's successful Mystic unit, only one other magnesium-oxide system is now in operation. This 100-megawatt scrubber, also designed by Chemico, is being operated by Potomac Electric Power Company at Dickerson No. 3. Start-up took place in September 1973, but full operation was not begun until July 1974 when the regeneration facility became available. This system represents the first large-scale application of the magnesium-oxide process to a coal-fired boiler.

Illinois Power Company has at its Wood River station the only catalytic oxidation system operating in the U. S. The 110-megawatt scrubber designed by Monsanto started-up in September 1972 and was accepted from the vendor after completion of testing in July 1973. Mechanical difficulties experienced during shakedown called for modifications which are now nearly complete. The scrubber is scheduled to start-up for continued operation this month.

The Nevada Power Company is now testing two aqueous sodium base scrubbers at its Reid Gardner station and will start-up a third unit there next year. The 125-megawatt units have only been on-line for a short time but excellent test results have already been cited and performance seems promising.

SLUDGE DISPOSAL

It is recognized that large quantities of semi-solid sludge are produced by lime and limestone scrubbing systems and that this sludge must be carefully disposed of to avoid any adverse impact on the environment. EPA does not view sludge disposal as an insurmountable problem,

however, since disposal methods are now offered commercially that treat sludge in an environmentally acceptable manner. Wet sludge can be hardened (fixated) through chemical reactions to form a dry, solid, largely inert material or it can be ponded.

Although fixation technologies are offered commercially, many companies have been temporarily ponding sludge while concentrating on improving reliabilities of their FGD systems. Now that scrubber operating problems are being solved and system reliabilities are improving, more sludge is being generated by lime/limestone units and utilities are beginning to focus more attention on techniques for disposing of sludge. For example, full-scale sludge fixation is now underway at at least two U. S. power plants. Commonwealth Edison fixates sludge from its Will County scrubber and stores the product on-site. The company plans to ultimately dispose of the sludge in an off-site landfill area. Duquesne Light is now fixating sludge from three boilers at the Phillips plant. This fixated sludge is temporarily stored in on-site ponds, then hauled to off-site lined ponds for disposal. It is ultimately planned to dispose of this fixated sludge in unlined ravines. In addition, a prototype facility at Southern California Edison's Mohave station fixates the sludge, discharging part of the treated sludge to a concrete-lined disposal site. The remaining sludge is used to manufacture aggregate pellets which can be used as a concrete admixture.

Chemically fixated sludge has several uses, the most important of which is landfill. Numerous landfill sites are available in the U. S., especially in areas where coal has been strip-mined. Fixated sludge can be used to restore such land to its original condition. Limited use is possible in such other applications as roadbase.

Wet sludge can also be ponded, and where leaching into ground or surface water is feared, ponds can be lined with an impermeable liner or constructed with a drainage system to collect and isolate any leachate.

Sludge disposal problems occur, however, only with lime and limestone scrubbing systems. Where disposal of such sludges is impractical because of geographic location, space availability, or other considerations, alternative FGD systems can be used. Regenerable systems, such as magnesium-oxide, catalytic oxidation, and Wellman-Lord processes, do not produce sludge. Rather, these systems regenerate the scrubbing agent and produce such valuable materials as sulfuric acid and elemental sulfur.

SUMMARY & CONCLUSIONS

The past year has seen a major increase (over 100%) in the commitment of utilities to the installation of FGD controls. While

the commitment to control 35,000 megawatts of generating capacity is still short of the need,[4] it represents a rapidly growing acceptance by utilities of the need for and workability of FGD controls.

While a few utilities continue to argue that FGD systems have not yet demonstrated reliable operation, actual experience over the past few months clearly refutes these claims. Experiences at Louisville Gas and Electric, Arizona Public Service, and Southern California Edison are illustrative. LG&E's Paddy's Run unit has been available to the boiler for a total of 5 months at well over 90% reliability. APS's Cholla unit has operated continuously for 8 months with a reliability of 90% or better, and SCE's Mohave unit has operated continuously from January to September 1974 at 84% reliability.

Based on FGD operating experience to date, the availability of commercial methods to treat sludge wastes, and the rapidly growing commitment of utility companies to install FGD, no other conclusion can be reached than that flue gas desulfurization systems are available and can be used to continuously, reliably, and effectively control sulfur oxide emissions from power plants.

[4] In the national hearing panel's report, EPA estimated that to meet primary ambient air quality standards and new source performance standards through 1980 the use of some 90,000 megawatts of FGD control would be required.

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Table I

SUMMARY OF ELECTRIC UTILITY
FLUE GAS DESULFURIZATION FACILITIES

MW Capacity (No. of Units)

PROCESS	OPERATIONAL	UNDER CONSTRUCTION	PLANNED	TOTALS	NEW PLANTS	RETROFIT ON EXISTING PLANT
Limestone	1076(3)	1525(4)	1330(2)	3931(9)	4	5
Lime	725(4)	2930(6)	750(1)	4405(11)	7	4
Magnesium Oxide	250(2)	120(1)	---	370(3)	-	3
Catalytic Oxidation	110(1)	---	---	110(1)	-	1
Wellman-Lord	---	115(1)	---	115(1)	-	1
Aqueous Na Based	---	375(3)	---	375(3)	-	3
Dry Absorption	---	150(1)	---	150(1)	-	1
Process Not Selected	---	---	8569(15)	8569(15)	8	7
TOTAL	2161(10)	5215(16)	10649(18)	18025(44)	19	25

September 18, 1974

Table II

ELECTRIC UTILITY
FLUE GAS DESULFURIZATION FACILITIES

PROJECTED START-UP DATE

1974	1975	1976	1977	1978	1979	1980	1983	Unknown
3	10	12	19	10	14	4	1	1

September 18, 1974

Table III

SUMMARY OF ELECTRIC UTILITY
FLUE GAS DESULFURIZATION FACILITIES

MW Capacity (No. of Units)

PROCESS	OPERATIONAL	UNDER CONSTRUCTION	PLANNED	TOTALS	NEW PLANTS	RETROFIT ON EXISTING PLANTS
Limestone	1904 (8)	1570 (4)	13027(27)	16501(39)	29	10
Lime	715 (4)	2910 (5)	5038(18)	8663(27)	8	19
Limestone or Lime	30 (1)	--	6085(10)	6115(11)	7	4
Magnesium Oxide	250 (2)	120 (1)	487 (2)	857 (5)	--	5
Catalytic Oxidation	110 (1)	--	--	110 (1)	--	1
Wellman-Lord	--	830 (3)	--	830 (3)	1	2
Aqueous Na Based	250 (2)	125 (1)	--	375 (3)	--	3
Double Alkali	32 (1)	--	--	32 (1)	--	1
Process Not Selected	--	--	1900 (3)	1900 (3)	2	1
TOTALS	3291(19)	5555(14)	26537(60)	35383(93)	47	46

Table IV

STATUS

FLUE GAS DESULFURIZATION UNITS ON POWER PLANTS
PRESENTLY OPERATIONAL AND UNDER CONSTRUCTION

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Limestone Scrubbing					
Kansas Power & Light Lawrence No. 4	R	125	CE	Coal, 3.5%	Dec. 1968
Operational Experience -- Limestone boiler injection; many problems including corrosion, plugging, and reheater/demister difficulties; no significant scaling problems. Performance unsatisfactory due to poor scrubber control and lime distribution in scrubber; efficiency up to 85% but operation erratic -- system to be converted to tail-end scrubbing with limestone. The two modules on unit No. 4 have been available essentially 100% during August 1974.					
Sludge Practices -- Three unlined ponds; overload encountered.					
Kansas Power & Light Lawrence No. 5	N	400	CE	Coal, 3.5%	Nov. 1971
Operational Experience -- Same problems as Lawrence No. 4 with added problem of scaling when both units attempted to use an inadequate sized pond. Performance unsatisfactory due to poor scrubber control and gas distribution to the eight modules; efficiency up to 85%, but operation erratic. The system will be converted to tail-end scrubbing with limestone. Unit No. 5 has operated on gas and oil during August 1974.					

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Sludge Practices	— Three unlined ponds; overload encountered.				
Commonwealth Edison Will County No. 1	R	167	B&W	Coal, 3.5%	Feb. 1972
Operational Experience	— Feb. 1972 to Nov. 1973 — intermittent operation with 80-90% SO_2 removal; many mechanical problems including demister/reheater pluggage, wearing and plugging of spray nozzles, reheater vibration and stress corrosion cracking, plugging of slurry lines, "sulfite blinding", and scaling. Other reasons for outage are expansion joint failure, contractor/operator errors, fan trip, water loss, faulty damper operation, leaks, inadequate limestone supply, and booster fan vibration. Through the end of 1972, scrubber A operated 1726 hours for an availability of 27%; scrubber B operated 328 hours for an availability of 5.1%. Nov. 1973 to present — loss of building heat caused extensive freeze damage; washing system modified to continuous river-water wash as underspray plus intermittent overspray wash using pond water. Chlorides have caused problems in reheaters. Scrubber B was shut down on April 13, 1973, and is awaiting internal modifications to perforated trays. Scrubber A availability has generally improved recently and was 72% in April, 93% in May, 54% in June, 95% in July, and 91% in August. The lower availability in June was due to a plugged venturi throat. Company considering conversion of the scrubbers to particulate control only.				
Sludge Practices	— Presently using lined ponding; working with Chicago Fly Ash on final treatment process; the State has issued a development permit to the Contractor (Materials Services Company) for sludge disposal at the Contractor-owned site; an operating permit has been requested and is expected in the near future.				
Kansas City Power & Light, Hawthorn No. 4	R	100	CE	Coal, 3.5%	August 1972
Operational Experience	— Formerly limestone boiler injection, recently converted to tail-end system. 70% SO_2 removal. No recent problems with fans or reheaters; remaining problems appear to be with recirculation system, including headers and drain pots; demister pluggage was a problem but is presently under control; some scaling has occurred in the recirculation tank requiring tank modification and agitation improvements.				

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up

Vendor says system has operated since 2/74 with no major problems, although scrubber/demister must be cleaned by hand during periods of boiler downtime.

Sludge Practices — Presently using ponding, unlined; numerous well points for testing ground water; fly ash contamination in pond masks test results; land area for ponding sufficient for 15 years.

Kansas City Power & Light, Hawthorn No. 3	R	140	CE	Coal, 3.5%	Nov. 1972

Operational Experience — Limestone boiler injection; no boiler pluggage; problems essentially the same as those described for Hawthorn No. 4.

Sludge Practices — Same as Hawthorn No. 4.

City of Key West Key West	N	37	Zurn	Oil, 2.4%	Oct. 1972

Operational Experience — Scrubber is not presently operating because the by-pass damper is jammed open. During performance tests in August 1973, SO_2 removal efficiency was approximately 75%. The system consists of two Zurn Air Systems Dustraxtor scrubbers, each of which has 24 vertical 12" ID tubes which pass flue gas and entrained limestone slurry. Total operation to date consists of 400 hours. A major problem has been the coral grinding system — initially the venturi installed for dust removal was unsatisfactory. The baghouse which replaced the venturi plugs after only 4 hours of operation; corrective actions (increasing the number of bags, using lighter, thinner bags, using teflon coated bags, and increasing purge air pressure) are presently being evaluated.

Kansas City Power & Light, LaCygne No. 1	N	820	B&W	Coal, 5%	June 1973

Operational Experience — Seven modules each consisting of a two-stage scrubbing system — venturi and grid tower. Very similar to the Commonwealth Edison Will County Unit. This system is not equipped with by-pass or ESPs. Unit was designed to operate with

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up

7 modules taking the total load. An eighth module was to serve as a spare. Initial problems included induced draft fan deposits and erosion, demister pluggage, nozzle pluggage, reheater coil failures (corrosion/erosion), pump screens pluggage. Most of the problems are attributable to poor pH control which results from inadequate instrumentation.

Pluggage problems in the venturi hoses and nozzles were solved by the addition of cyclone separators which reduced the solids content of the spray liquor. Sulfate scaling on the demisters has been significantly diminished by using 50% clear H_2O for the demister spray. In addition, heavier demisters (1/8" rather than 1/16") and overlapping chevrons are expected to improve the operability of the system. The plant is looking for a way to monitor solids carry-over which forms deposits on fan blades. The venturis in all seven modules are currently in use. SO_2 removal efficiency across the venturi and absorber combination is approximately 70%. Although the station's rating is 848 MW, the net power rate leaving the plant is 790 MW due to use of auxiliary power required to operate FGD process and "stealing" of hot air from boilers to supplement the steam reheating of the scrubber effluent gases to 190-200°F.

Sludge Practices — Presently using ponding, unlined.

Arizona Public Service Cholla No. 1	R	115	Research-Cottrell	Coal, 0.4-1.0%	Dec. 1973

Operational Experience -- System availability from January 1974 through July 1974 averaged 89% for both modules. Module A (SO_2 and particulate scrubbing) availability was 92% and module B (particulate scrubbing only) availability was 87% Downtime was attributed to rewiring, leak repair, packing gland repair, meter calibration, reheater vibrations, instrumentation, inspect reheater tube bundles, repair reheater tube bundles. SO_2 /particulate removal efficiencies are 92%/99% --particulates removed in flooded disc venturi scrubber and SO_2 removed in packed tower. Acid condensation on reheater tubes stopped by insulating -- reheater vibration stopped by cross baffles at inlet. 15% solids sent to pond. Replaced expansion joint on reheater. Scrubber system availability for August was 93 % Module A availability was 98%

Sludge Practices — Presently using unlined ponding and evaporation; due to water shortage, Research Cottrell is attempting to maximize water recovery and recycling.

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Southern California Edison (operating agent) Mohave No. 1	R	160	UOP	Coal, 0.5-0.8%	Under Construction (Oct. 1974)
Operational Experience	-- Originally scheduled for start-up in January 1974 but delayed until October by extensive fire damage.				
Sludge Practices	-- Ponding planned; IUCS & Dravo are developing sludge treatment/disposal techniques on-site and are competing for contract.				
Detroit Edison St. Clair No. 6	R	180	Peabody Engineering	Coal, 3.7%	Under Construction (Jan. 1975)
Sludge Practices	-- Unfixed ponding planned.				
TVA Widow's Creek No. 8	R	550	TVA	Coal, 3.7%	Under Construction (May 1975)
Sludge Practices	-- Unlined ponding planned; have acquired new large area for ponding; EPA's CSL evaluating chemical fixation and clay ponding at TVA's Shawnee Plant.				
Northern States Power Sherburne County No. 1	R	680	CE	Coal, 1%	Under Construction (May 1976)
Sludge Practices	-- Ponding planned; clay lined.				

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Lime Scrubbing					
Louisville Gas & Electric, Paddy's Run No. 6	R	65	CE	Coal, 3%	April 1973

Operational Experience — ESP followed by 2 parallel, 2-stage marble bed scrubbers. Unit operated at 70% availability to boiler since start-up in April to December 1973. From October to December 1973 the availability was greater than 90%. The boiler was shut-down in December 1973 because of low demand, and restarted with FGD operation during July 1974. The FGD unit has been operating at 100% availability since the recent start-up. SO_2 removal is 90% -- no scaling, plugging, erosion, or corrosion. Early problems were minor and mechanical in nature. The demisters have caused no problems. The system is essentially closed loop-operation, and the FGD system has effectively followed the varying boiler load.

Sludge Practices — Sludge is filtered and used for land fill in a ravine; this is a small plant, it is a pilot test for large system.

Southern California Edison (operating agent) Mohave No. 2	R	160	SCE/ Stearns-Roger	Coal, 0.5-0.8%	Nov. 1973

Operational Experience -- The formal test program for SCE started January 1974. The horizontal absorber had logged 3200 operating hours (better than 75% availability) as of July 24, 1974 in the "research mode." The overall availability of the horizontal absorber from January 1, 1974 to September 13, 1974 has been 84%. The scrubber has operated with good reliability and no major operational problems to date. No severe plugging or scaling has occurred in any of the tests.

Sludge Practices — Ponding planned; IUCS and Dravo are developing sludge treatment/disposal techniques on-site and are competing for contract.

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Duquesne Light Company Phillips Station	R	410	Chemico	Coal, 2%	March 1974

Operational Experience — Brief start-up with water for fly ash removal led to erosion problems, particularly with fans. Shut-down for fan maintenance, including modification of fan spray wash and completion of lime feed system.

Restart March 17-22, 1974 with lime added to 2-stage scrubber train and to one of three one-stage trains. Three of six plant boilers currently tied into scrubber system (approx. 40% of plant generating capacity). No operating problems of plugging with scrubbers, although wet induced draft fans have minor solid deposition and corrosion problems. Other problems include difficulties with transporting sludge treatment chemical slurry to pond area, excess water in system (primarily from fan wash and excess fly ash solids because of reduced ESP efficiency caused by high velocity in scrubber duct tie-in.

Operating hours for modules 1 through 4 between March 17, 1974 and June 30, 1974 were 1756, 762, 815, 1707 respectively. Modules 1 and 4 are considered primary scrubbers and the plant attempts to run these continuously.

Sludge Practices — Three small lined ponds on site; plant has two areas in a ravine for sludge deposits; planning fixation process in large ravines using Dravo technology.

Dairyland Power Coop. Alma Station	R	80	Foster Wheeler	Coal, 3.0-3.5%	August 1971

Operational Experience — The FGD system is a demonstration project consisting of lime (CaO) mixed with water and injected into the upper boiler under pressure. Short run tests are conducted in conjunction with a slip stream ESP. During the test runs the FGD system availability was 90% and efficiency of SO_2 removal was 50%

Duquesne Light Company Elrama Station	R	510	Chemico	Coal, 2%	Under Construction (1974)

Operational Experience — The five venturi scrubber trains which were designed to remove particulates only will eventually be modified to remove SO_2. The start-up of the scrubbers was delayed to evaluate operating problems at the Phillips Station.

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Pennsylvania Power Mansfield No. 1	N	880	Chemico	Coal, 4.3%	Under Construction (Early 1975)
Sludge Practices	— Plan calls for pumping sludge several miles into a dammed ravine; Dravo contract calls for treating sludge for fixation.				
Pennsylvania Power Mansfield No. 2	N	800	Chemico	Coal, 4.3%	Under Construction (Early 1975)
Sludge Practices	— Plan calls for pumping sludge several miles into a dammed ravine; Dravo contract calls for treating sludge for fixation.				
Montana Power Colstrip No. 1	N	360	CEA	Coal, 0.8%	Under Construction (May 1975)
Montana Power Colstrip No. 2	N	360	CEA	Coal, 0.8%	Under Construction (May 1975)
Limestone or Lime					
TVA Shawnee No. 10	R	30	TVA	Coal	April 1972
Operational Experience	-- This is an experimental system funded by U. S. EPA. The facility consists of 3 parallel scrubber systems: 1) venturi followed by a spray tower; 2) turbulent contact absorber (TCA); and 3) marble bed absorber. Each system is capable of treating 10 MW equivalent of flue gas containing 1000-4000 ppm SO_2 and 2-5 grains/scf particulates. --The following test blocks have been defined for the program: 1) air/water testing; 2) sodium carbonate; 3) limestone wet scrubbing; 4) lime wet scrubbing. The major test goals are: 1) to characterize the effect of process variables on SO_2 and particulate removal; 2) to develop mathematical models to allow economic scale-up of optimum operating configurations; and 3) to perform long-term reliability testing. Experimental test runs are planned up to 1976. Excellent potential for high efficiency and reliability is indicated from results to date with lime and limestone scrubbing employing the TCA and venturi/spray tower.					

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Magnesium Oxide Scrubbing					
Boston Edison Mystic No. 6	R	150	Chemico	Oil, 2.5%	April 1972

Operational Experience -- From April 1972 to May 1973 many process and mechanical problems developed and were constantly being worked on and corrected. During this 13 month period the scrubber availability was approximately 17%. Efficiency during this period from limited testing indicated 90% SO_2 removal using virgin MgO and 80% using regenerated MgO. Slacking and pumping problems occurred during the use of regenerated MgO.

The following scrubber availability are reported for 1973: June -- 68%, July -- 61%, August -- 73%, September -- 38%, October -- 60%, November -- 26%, and December -- 13%. The decreasing availability during this seven month period was due to deterioration of equipment from erosion/corrosion.

The availability during January 1974 was 28% and 25% for Feb. 1974. During this period a lot of overhaul work was carried out. Near the end of February 1974 a performance test indicated a SO_2 removal efficiency of 91% and 50% for particulates using regenerated MgO.

The following availabilities were recently obtained: March 1974 -- 87%, April 1974 -- 81%, May 1974 -- 57%, and June 1974 -- 80% SO_2 removal efficiency was 80-90%. The scrubber was shut-down on June 27. It will not be restarted because the 2 year project is completed and PEPCO (Dickerson No. 3) is now using the calcining facilities at Rumford, R.I.

Potomac Electric & Power Dickerson No. 3	R	100	Chemico	Coal, 2%	Sept. 1973

Operational Experience -- First large scale coal application of the Mag-Ox Process.

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
	Although the system has experienced some start-up difficulties, scrubber operation has been satisfactory to date. It should be noted that only the scrubber system had been operated until recently (July 1974) when the Rumford, R.I. regeneration facility was made available for PEPCO use, at the conclusion of Boston Edison's testing program. Plant is presently down for a few days to allow minor modifications to be made. No major problems reported.				
Philadelphia Electric Eddystone No. 1	R	120	United Engineers	Coal, 2.5%	Under Construction (Dec. 1974)
Catalytic Oxidation (Cat-Ox)					
Illinois Power Company Wood River No. 4	R	110	Monsanto	Coal, 3.2%	September 1972
Operational Experience — 85% SO_2 removal achieved; mechanical difficulties during initial operation indicated need for modifications — construction completed 10/72, but acceptance testing completed 7/73. Operational modifications in process — reheater burners being converted from natural gas to fuel oil. Modifications in process; operation scheduled for September 1974.					
Wellman-Lord					
Northern Indiana Public Service, D. H. Mitchell No. 11	R	115	Davy Powergas/ Allied Chemical	Coal, 3.5%	Under Construction (Mid 1975)
Public Service of New Mexico San Juan No. 1	N	375	Davy Powergas	Coal, 0.8%	Under Construction (1977)

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Public Service of New Mexico San Juan No. 2	R	340	Davy Powergas	Coal, 0.8%	Under Construction (1977)
Aqueous Sodium Base Scrubbing, Non-Regenerable					
Nevada Power Reid Gardner No. 1	R	125	CEA	Coal, 0.5-1.0%	May 1974
Operational Experience -- System performs satisfactorily when there is sufficient Trona (impure form of sodium carbonate). There are no outstanding process problems. However, the plant is running out of Trona and operates only intermittently. Supplier will not deliver Trona before 3d quarter of 1975.					
Nevada Power Reid Gardner No. 2	R	125	CEA	Coal, 0.5-1.0%	May 1974
Operational Experience -- Same as Reid Gardner No. 1. Excellent initial test results obtained with Reid Gardner No. 2.					
Nevada Power Reid Gardner No. 3	R	125	CEA	Coal, 0.5-1.0%	Under Construction (1975)
Double Alkali (Sodium/Calcium) Throwaway Product					
General Motors Parma Chevy Transmission Plant Cleveland, Ohio	R	32	GM	Coal, 2.5%	April 1974
Operational Experience -- General Motors announced continuous operation for 624 hours as of April 31, 1974. the system was shut-down from May 1-May 28 due to the unexpected build-up of solids in the clarifier with subsequent overflow into the scrubber. This problem was corrected by (1) using a polymeric flocculating agent to attain better settleability and (2) withdrawing sludge from the clarifier at more frequent					

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up

intervals. The system has been in operation since May 29 except for brief, non-scrubber related shut-downs. Pluggage by $CaCO_3$ deposits in the overflow line between the clarifiers and in the line from Clarifier 2 to mix tanks has been a problem. The scrubber availability to the boiler has been 87% in April, less than 10% in May, and 100 percent for June, July and August 1974. The efficiency of SO_2 removal was determined to be 98 percent.

Table V

PLANNED FLUE GAS DESULFURIZATION UNITS ON POWER PLANTS

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Contract Awarded					
Columbus & Southern Ohio Conesville No. 5	N	375	Lime UOP	Coal	1976
Columbus & Southern Ohio Conesville No. 6	N	375	Lime UOP	Coal	1976
Kansas Power & Light Jeffery No. 1	N	700	Limestone CE	Coal, 0.3%	1979
Kansas Power & Light Jeffery No. 2	N	700	Limestone CE	Coal, 0.3%	1979
Kansas Power & Light Jeffery No. 3	N	700	Limestone CE	Coal, 0.3%	1979
Kansas Power & Light Jeffery No. 4	N	700	Limestone CE	Coal, 0.3%	1979
Kentucky Utilities Green River 1, 2, & 3	R	64	Lime Am. Air Filter	Coal, 3.8%	1975
Louisville Gas & Electric Cane Run No. 4	R	178	Lime Am. Air Filter	Coal, 3.5-4.0%	1975

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Louisville Gas & Electric Mill Creek No. 3	R	425	Lime Am. Air Filter	Coal, 3.5-4.0%	1977
Northern States Power Sherburne County No. 2	N	680	Limestone CE	Coal, 1.0%	1977
Public Service Indiana Gibson	N	650	Limestone CE	Coal, 1.5%	1976
Southwestern Pub. Ser. Harrington No. 1	N	343	Lime CE	Coal, 0.5%	1976
Springfield Utility Board Southwest No. 1	N	200	Limestone UOP	Coal	1976
Texas Utilities Martin Lake No. 1	N	793	Limestone RC	Coal, 0.4%	1976
Texas Utilities Martin Lake No. 2	N	793	Limestone RC	Coal, 0.4%	1977
Texas Utilities Martin Lake No. 3	N	793	Limestone RC	Coal, 0.4%	1978
Texas Utilities Martin Lake No. 4	N	793	Limestone RC	Coal, 0.4%	1979
Letter of Intent Signed					
Arizona Electric Power Apache No. 2	N	200	Limestone Research Cottrell	Coal, 0.5-0.8%	1979
Arizona Electric Power Apache No. 3	N	205	Limestone Research Cottrell	Coal, 0.5-0.8%	1979

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Arizona Public Service Cholla No. 2	N	250	Limestone Research Cottrell	Coal, 0.4%	1977
Arizona Public Service Cholla No. 3	N	250	Limestone Research Cottrell	Coal, 0.4%	1978
Out for Bids					
Central Illinois Pub. Ser. Duck Creek No. 1	N	100	Limestone Riley Stoker/ Environeering	Coal	1976
Central Illinois Pub. Ser. Newton No. 1	N	600	Limestone/Lime	Coal, 2.8-3.2%	1977
Cincinnati Gas & Electric Miami Fort No. 8	N	500	Limestone/Lime	Coal, 3.2%	1977
General Public Utilities Homer City No. 3	N	650	Not Selected	Coal	1977
Indianapolis Power & Light Petersburg No. 3	N	515	Limestone/Lime	Coal, 3.5%	1977
South Carolina Pub. Ser. Georgetown No. 2	N	140	Limestone/Lime	Coal, 1.0%	1977
Texas Utilities Monticello No. 3	N	800	Limestone	Coal, 0.8-1.0%	1978
Conducting Engineering Studies					
Arizona Public Service Four Corners No. 1	R	175	Lime Chemico	Coal, 0.8%	1976

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Basin Electric Missouri Basin No. 1	N	550	Limestone	Coal	1979
Basin Electric Missouri Basin No. 2	N	550	Limestone	Coal	1980
Basin Electric Missouri Basin No. 3	N	550	Limestone	Coal	1983
Cincinnati Gas & Electric East Bend No. 1	N	600	Not Selected	Coal, 0.5-0.8%	1979
Colorado Utility Electric Craig No. 1	N	450	Limestone	Coal, 0.5%	1978
Colorado Utility Electric Craig No. 2	N	450	Limestone	Coal, 0.5%	1978
Colorado Utility Electric Hayden No. 1	R	202	Limestone	Coal, 0.5%	1978
Colorado Utility Electric Hayden No. 2	R	250	Limestone	Coal, 0.5%	1978
New England Electric System Brayton Point No. 3	R	650	Not Selected	Coal, 0.3%	—
Salt River Project Navajo No. 1	N	750	Limestone/Lime	Coal, 0.5-0.8%	1976
Salt River Project Navajo No. 2	N	750	Limestone/Lime	Coal, 0.5-0.8%	1976

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Salt River Project Navajo No. 3	N	750	Limestone/Lime	Coal, 0.5-0.8%	1977
Southern Calif. Edison Mohave No. 1	R	640	Limestone/Lime	Coal, 0.5-0.8%	1977
Southern Calif. Edison Mohave No. 2	R	640	Limestone/Lime	Coal, 0.5-0.8%	1977
Southern Miss. Power Co. Hattiesburg No. 1	N	223	Limestone	Coal	1979
Southern Miss. Power Co. Hattiesburg No. 2	N	223	Limestone	Coal	1979
Initial Planning Stage					
Arizona Public Service Cholla No. 4	N	372	Limestone	Coal	1979
Arizona Public Service Four Corners No. 2	R	175	Lime Chemico	Coal, 0.8%	1977
Arizona Public Service Four Corners No. 3	R	229	Lime	Coal, 0.8%	1977
Arizona Public Service Four Corners No. 4	R	800	Lime Chemico	Coal, 0.8%	1977
Arizona Public Service Four Corners No. 5	R	800	Limestone/Lime	Coal, 0.8%	1977
Louisville Gas & Electric Cane Run No. 1	R	110	Lime	Coal, 3.5-4.0%	1980

Utility Company Power Station	New or Retrofit	Size of FGD Unit (MW)	Process Vendor	Fuel and Sulfur Content	Start-Up
Louisville Gas & Electric Cane Run No. 2	R	107	Lime	Coal, 3.5-4.0%	1980
Louisville Gas & Electric Cane Run No. 3	R	137	Lime	Coal, 3.5-4.0%	1980
Louisville Gas & Electric Cane Run No. 5	R	183	Lime	Coal, 3.5-4.0%	1976
Louisville Gas & Electric Cane Run No. 6	R	277	Lime	Coal, 3.5-4.0%	1977
Louisville Gas & Electric Mill Creek No. 1	R	330	Lime	Coal, 3.5-4.0%	1979
Louisville Gas & Electric Mill Creek No. 2	R	330	Lime	Coal, 3.5-4.0%	1978
Louisville Gas & Electric Mill Creek No. 4	R	425	Lime	Coal, 3.5-4.0%	1979
Philadelphia Electric * Cromby No. 1 (or No. 2)	R	153 (or 201) *	Mag-ox United Eng.	Coal, 2.5%	1978
Philadelphia Electric Eddystone No. 2	R	334	Mag-ox United Eng.	Coal, 2.5%	1978

* Utility is undecided as to which boiler to retrofit with FGD.